Advanced QFT course

1. Systematics of renormalisation (JC 3). Dimensional regularization (JC 4).
2. Counter terms to Feynman graphs, recursive procedure (JC 5.1-5.4). Proof of locality (JC 5.8).
3. BPHZ forest formula (JC 5.4-5.5). Relation to Lagrangian counter terms (JC 5.6).
4. Renormalization of composite operators (JC 6.1-6.4).
5. Equation of motion, Ward identity. Nonrenormalization of conserved currents (JC 6.6).
6. Generating functional, perturbation theory, DS equations (RR 1.1-1.5). Connected diagrams, Hartree-Fock equation. Classical limit and tree graphs (RR 2.1).
7. 1PI and effective action, effective potential (RR 2.2). Background field method (RR 4.6).
8. Quantisation of non-Abelian gauge theories, Faddeev-Popov ghosts and Feynman rules (PS 16).
9. One-loop effective potential for O(N) model (PS 11.4) and in theories with scalars, fermions and gauge fields (RR 13.1-13.2).
10. Spontaneous symmetry breaking, Goldstone theorem (RR 12.1, PS 11). Renormalisation of symmetry in general (PS 11). Convexity (RR 13.5-13.6). Mermin-Wagner theorem (MW).
11. Radiatively generated symmetry breaking (PS 11.4), improved effective potential (PS 13.2).
12. Instantons and tunnelling in quantum mechanics (SC 7.2).
13. Decay of the false vacuum in quantum field theory (SC 7.6).

Optional topics

- Trace anomaly (JC 6.5). The Callan-Symanzik equation as the anomalous Ward identity of scale invariance (PS 19.5).
- Infrared divergences (PS 6)

References

[JC] J.C. Collins: *Renormalization*, Cambridge University Press, 1984.
[IZ] C. Itzykson and J.-B. Zuber: *Quantum Field Theory*, McGraw-Hill, 1980.
[MW] S. Coleman: There are no Goldstone Bosons in Two Dimensions. *Commun. Math. Phys.* **31**: 259-264 (1973).
[PS] M.E. Peskin and D.V. Schroeder: *An Introduction to Quantum Field Theory*, Perseus Books, 1995.
[RR] R.J. Rivers: *Path Integral Methods in Quantum Field Theory*, Cambridge University Press, 1990.
[SC] S. Coleman: *Aspects of Symmetry*, Cambridge University Press, 1985.

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Advanced QFT seminar projects

1. Dimensional regularisation: definition, continuation to small d, properties 1-5 (JC 65b-75).
2. Dimensional regularisation: properties 6-10, formulae for Minkowski space, Dirac matrices (JC 75-87)
3. Zimmermann's forest formula (JC 109-112) + BPHZ renormalisation (JC 133-135)
4. Renormalisation of ϕ^2 and $\phi^2(x)\phi^2(y)$ (JC 139-146)
5. Operator product expansion in ϕ^4 theory (JC 257-263)
6. Optical theorem (PS 230-237)
7. Unitarity and ghosts (PS 506-512 plus 515-517)
8. Reduction formula 1. Scalar field (IZ 202-212)
9. Reduction formula 2. Fermion field and photons (IZ 213-222)
10. BRST symmetry in gauge theory (PS 517-521, + basic facts on Lie algebras PS 495-502)
11. Coleman-Weinberg mechanism.
(http://www.scholarpedia.org/article/Coleman-Weinberg_mechanism,
Rivers 241-246. See also PS 469-470)
12. Double well with instantons (Coleman 270-277, 340-344)
13. Anomaly in Schwinger model (PS 651-659)
14. Axial anomaly in 4D (PS 659-667)

Optional topics

- Nonlinear σ-model in $d = 2$ (PS 454-460)
- Nonlinear σ-model in $2 < d < 4$ (PS 461-466, except critical exponents)
- $1/N$ expansion (SC 351-368)
- Large mass expansion (JC 222-230)
- Asymptotic freedom with background field method (PS 533-540)